7 *IN SITU* GAMMA SPECTROMETRY AND EXPOSURE RATE MEASUREMENTS

The use of spectrometric techniques to assess radioactivity may produce a significant increase in sensitivity as compared to radiation measurements that rely on gross instrument counts. Spectrometry allows a specific radionuclide to be measured, relying on characteristic energies of the radionuclide of concern to discriminate from all sources present. *In situ* gamma spectrometry refers to the assessment of the ambient gamma ray flux that is collected in the field (i.e., *in situ*), and analyzed to identify and quantify the radionuclides present.

The Environmental Measurements Laboratory (EML) has performed detailed and quantitative evaluations of portable gamma spectrometry systems. The reader is referred to "Measurement Methods for Radiological Surveys in Support of New Decommissioning Criteria (Draft Report for Comment)" (NUREG-1506) for detailed guidance on how to employ *in situ* gamma spectrometry during survey activities. That report gives examples of minimum detectable concentrations using a typical 25-% relative efficiency p-type germanium detector and a 10-minute count time at typical background radiation levels. Using these assumptions, the minimum detectable concentrations (MDCs) for Co-60, Cs-137, Eu-152, Ra-226 (based on measurement of progeny) and Ac-228 (to infer Th-232) are all approximately 0.05 pCi/g. It is necessary to use a more efficient detector, such as a 75-% relative efficiency n-type germanium detector, to measure the radionuclides that are more difficult to detect. For example, using the 75-% relative efficiency n-type germanium detector for a 10-minute count time, results in an MDC of 0.5 pCi/g for Am-241, and 2 pCi/g for U-238 (based on measurement of short-lived Th-234 progeny) and Ra-226 (based on measurement of the 186 keV gamma energy line). These typical MDCs scale as the square root of the count time; that is, quadrupling the count time results in a factor of two increase in the sensitivity of the *in situ* measurement.

7.1 *In Situ* Gamma Spectrometry Measurements in Outdoor Test Area

In situ gamma spectrometry measurements were performed within the outdoor test area (this same area was also used to evaluate the scan sensitivity of surveyors) to determine the spectrometer's ability to identify and locate the sources. It should be understood that this particular exercise was intended to evaluate the scanning capabilities of the *in situ* gamma spectrometer, not its ability to determine radionuclide concentrations in soil, which requires detailed detector calibration and modeling of the contaminant distribution in the soil.

As stated in Section 6, 25 gamma-emitting sources were buried in the test area, including 12 Co-60 sources and 5 Cs-137 sources. Measurements were made at nine grid locations in the test area, at both 0.5 meter and 1 meter above the ground (Figure 7.1). A background measurement at 1 meter above the ground was performed in an adjacent area unaffected by the test area sources. ESSAP used a 13-% relative efficiency p-type germanium detector and a 30-minute count time at each measurement location. The net counts collected in both the Co-60 and Cs-137 peak regions were determined and are given in Table 7.1. The Co-60 data were presented in Figure 7.1 to allow a visual correlation between the detector response and the Co-60 source location. Cs-137 data were not evaluated in this manner because in only a few locations did levels of Cs-137 exceed background.

The results indicated that the portable gamma spectrometry system was able to identify the presence of Cs-137 and Co-60 contamination in the test area. This elementary finding warrants additional thought and should not be dismissed without consideration as to its implications on the use of *in situ* gamma spectrometry as a scanning tool. Recognizing that *in situ* gamma spectrometry is able to detect relatively low levels of gamma-emitting radionuclides is of particular value when the detector is used to verify the absence of contamination in an area. That is, if the detector's MDC can be demonstrated to be sufficiently below the contamination guidelines, then *in situ* gamma spectrometry measurements may be used to demonstrate that further survey efforts in an area are not warranted. Furthermore, using *in situ* gamma spectrometry to determine that residual radioactivity is below a specified concentration has an additional benefit in the improved documentation of the scan survey. Records of *in situ* gamma spectrometry measurements are generally more objective and less likely to be influenced by human factors than the conventional scan survey records obtained with NaI scintillation detectors or other portable field instrumentation, which require subjective interpretation of the detector response by the surveyor.

For the present experimentation, the *in situ* gamma spectrometer did identify the presence of Co-60 and Cs-137 contamination and, therefore, the data were analyzed in an effort to locate the contamination. Figure 7.1 shows the net counts in the Co-60 peak region at both 1 meter and 0.5 meter above the surface at each grid coordinate (top number is 1-meter value, bottom number is 0.5 m value). In the case of uniform contamination and a detector height of 1 meter, approximately 80% of the detector's response would be from a 5-meter radius (NUREG-1506). Because detector height above the surface affects the amount of ground being viewed, moving the detector closer to the ground results in a smaller section of the ground being viewed.

The greatest quantity of Co-60 activity was identified at grid location 15N,5W. The fact that the net counts for Co-60 increased as the detector was moved closer to the ground indicates that the source is relatively close to the sampled grid coordinate. Also, because the Co-60 result at coordinate 10N,5W has significantly less Co-60 activity than at 15N,5W, it is likely that the source is not south of grid coordinate 15N,5W.

The Co-60 results for grid coordinates 5N,5W and 15N,10W (both have 1-meter readings greater than 0.5-meter readings) indicate that Co-60 contamination is nearby, but not necessarily in the immediate vicinity of the sampled grid coordinate. Although this analysis does not direct the surveyor to the exact location of the contamination, it does provide for a focused plan for subsequent NaI scintillation scan surveys.

7.2 Exposure Rate Measurements in Outdoor Test Area

Exposure rate measurements using a pressurized ionization chamber (PIC) were performed within the outdoor test area to evaluate the PIC's sensitivity in measuring exposure rate. Measurements were performed at six grid coordinate locations, each reading at 1 meter above the surface (Figure 7.2). The background exposure rate (10.3 µR/h) was determined in an area adjacent to the test area, but unaffected by the test area sources.

The sensitivity of the PIC is directly proportional to the standard deviation of the background exposure rate. Therefore, areas exhibiting only minor background exposure rate variations will have the lowest minimum detectable exposure rates. The exposure rate measurements in the test area ranged from 10.2 to 11.1 µR/h (Table 7.2). Figure 7.2 illustrates the correlation between the exposure rate measurements and the source locations. The larger exposure rates correspond to the larger gamma radiation levels that were obtained during characterization of the test area (refer to grid locations 15N,15W and 15N,5W). These results indicate that the PIC response was affected by the gamma-emitting sources. The minimum detectable exposure rate obtained with the PIC can be expected to be approximately 1 µR/h above background levels, depending on the background variability.

Table 7.1 *In Situ* Gamma Spectrometry Data From Outdoor Test Area

Measurement Location[a]		Net Count in Peak Region	
		Cs-137 (662 keV)	Co-60 (1332 keV)
Background	1 m[b]	-4 ± 8	6 ± 14
5N, 5W	1 m	-18 ± 10	30 ± 10
5N, 5W	0.5 m	-4 ± 8	5 ± 16
10N, 5W	1 m	5 ± 7	27 ± 13
10N, 5W	0.5 m	15 ± 7	26 ± 12
15N, 5W	1 m	11 ± 8	163 ± 18
15N, 5W	0.5 m	-2 ± 7	234 ± 25
5N, 15W	1 m	-1 ± 8	38 ± 7
5N, 15W	0.5 m	4 ± 8	40 ± 13
10N, 15W	1 m	7 ± 9	9 ± 17
10N, 15W	0.5 m	8 ± 9	36 ± 15
15N, 15W	1 m	7 ± 8	40 ± 12
15N, 15W	0.5 m	-11 ± 9	18 ± 16
5N, 25W	1 m	7 ± 8	20 ± 18
5N, 25W	0.5 m	19 ± 9	23 ± 17
10N, 25W	1 m	3 ± 8	4 ± 17
10N, 25W	0.5 m	17 ± 8	36 ± 13
15N, 25W	1 m	-6 ± 8	8 ± 15
15N, 25W	0.5 m	10 ± 8	25 ± 11

[a]Refer to Figure 7.1.
[b]Distance refers to detector height above the surface.

Table 7.2 Exposure Rate Measurements From Outdoor Test Area

Measurement Location[a]	Exposure Rate[b] (μR/h)
Background	10.3
5N, 5W	10.8
5N, 15W	10.2
5N, 25W	10.9
15N, 5W	11.1
15N, 15W	11.0
15N, 25W	11.0

[a]Refer to Figure 7.2.
[b]Measurements made at 1 meter above the surface.

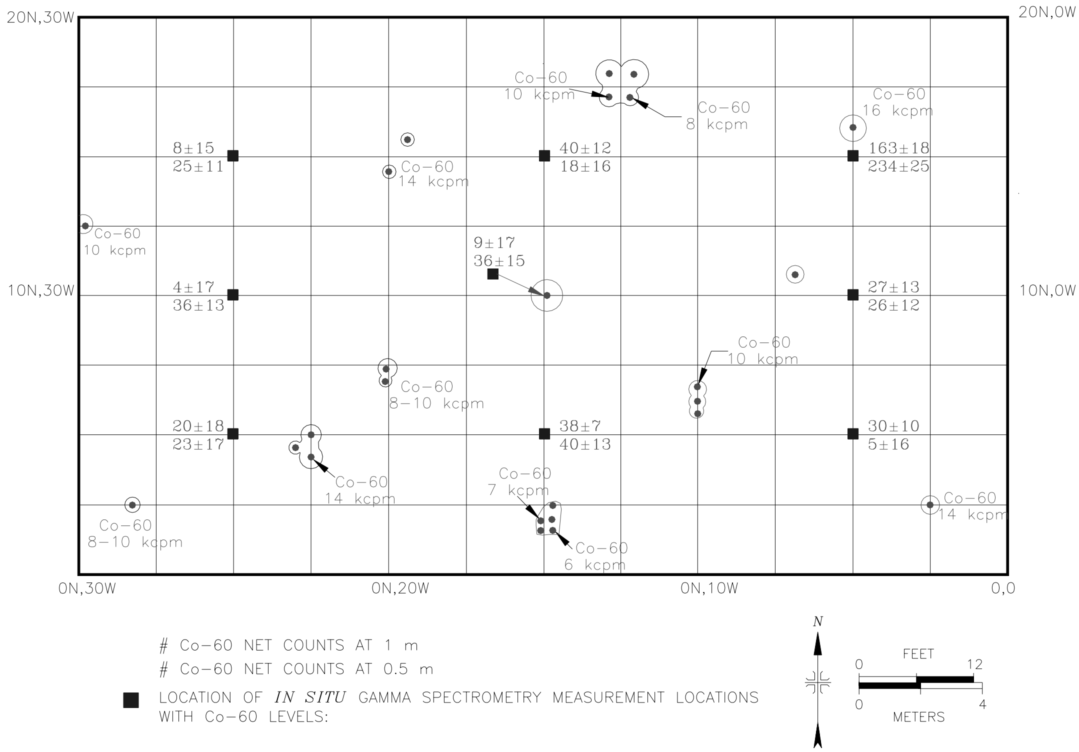

Figure 7.1: Co-60 *in situ* Gamma Spectrometry Results in Outdoor Test Area

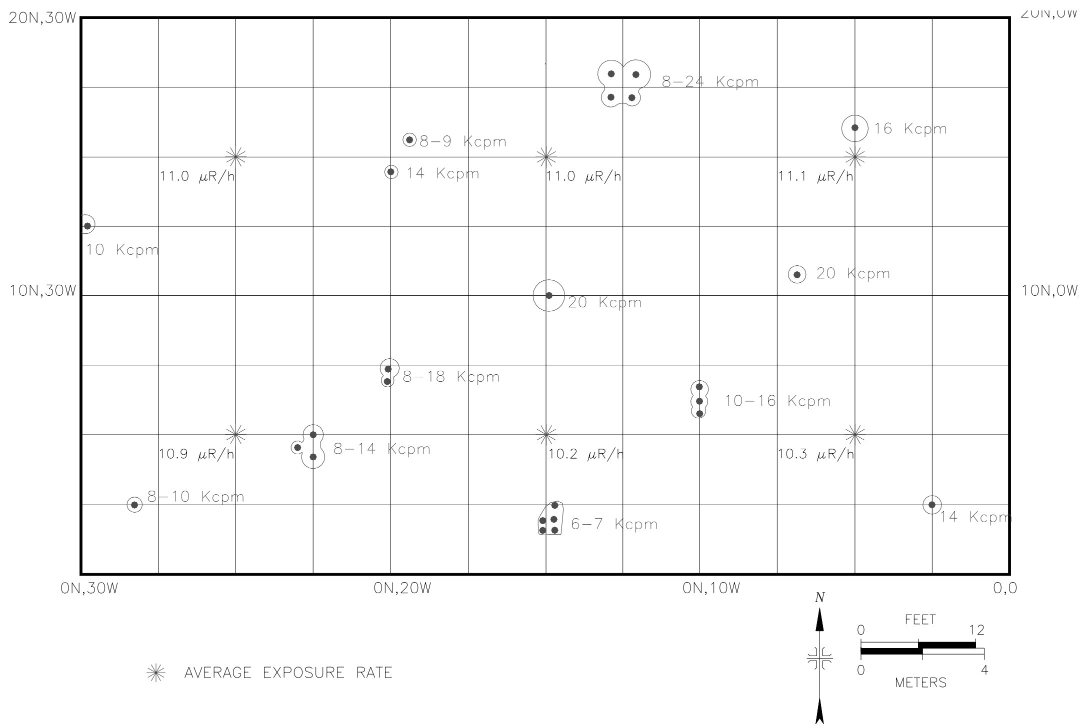

Figure 7.2: Exposure Rate Measurements in the Outdoor Test Area